



A review of the effects of COVID-19 on food waste

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Abstract

The COVID-19 pandemic exposed significant vulnerabilities in systems of production and consumption. In particular, the economic and social implications of the pandemic highlighted the urgent need for more sustainable and less impactful practices of food production and consumption. Through a systematic literature review, this paper seeks to assess how the pandemic affected the phenomenon of food waste, with the aim of assessing whether the pandemic stimulated changes amongst food system actors, especially consumers. The findings indicate that consumers generally reported behavioural changes during the pandemic and claimed to have adopted sustainable practices that could contribute to reducing food waste. The results also reflect the rapid diffusion of practices such as food delivery during the pandemic, which requires further investigation in terms of its effects on the environment. Simultaneously, supply–demand shocks and disruptions were reported in the areas of production, processing, and retailing, suggesting the occurrence of ripple effects. A call is made for greater resilience in the food system, through the adoption of sustainable and less impactful practices, supported by policy.

Keywords Food waste · COVID-19 · Food system · Sustainability

1 Introduction

In recent years, food waste – and its related environmental, economic, and social implications – has represented a pressing sustainability issue, worldwide. The magnitude of this phenomenon has been widely discussed by both scholars and international organisations, highlighting the high economic costs (amounting to billions of dollars per year; FAO, 2013) and environmental impact (in relation to CO₂ emissions, land degradation, and biodiversity loss; FAO, 2013). For this reason, food waste has been included and targeted in international strategies aimed at sustainability, including the UN Sustainable Development Goals (SDGs). In fact, it can be argued that a resolution to the problem of food waste would be beneficial for many SDGs, such as SDG 2 (‘Zero Hunger’), SDG 13 (‘Climate Action’), SDG 14 (‘Life below Water’), and SDG 15 (‘Life on Land’) (UN General

Assembly, 2015). However, a primary link can be made with SDG 12 (‘Responsible Consumption and Production’) (UN General Assembly, 2015). Specifically, Target 3 of SDG 12 seeks to, ‘[b]y 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses’ (UN General Assembly, 2015, p. 27).

According to the latest UNEP (2021) estimates, approximately 931 million tonnes of food produced for human consumption are either lost or wasted each year, amounting to 17% of global food production. Furthermore, food waste from households (UNEP, 2021) now represents 61% of the total global food waste, which is almost double the proportion recorded in 2011 (FAO, 2011). In recent years, several initiatives have been developed to support the SDGs and their targets. One of the most comprehensive of these strategies is the European Green Deal, which the EU laid out with the aim of becoming the first climate-neutral region by 2050. One of the focal points of the European Green Deal is the ‘Farm to Fork Strategy’, which seeks to improve the sustainability of food chains and systems, focusing on the link between healthy practices, healthy people, and a healthy planet (European Commission, 2020). As highlighted in the strategy, although a sustainable food system was needed

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even before COVID-19, the pandemic enhanced awareness of the need for greater resiliency in this context (European Commission, 2020).

In light of these considerations, this paper aims at analysing how the phenomenon of food waste has been impacted by recent changes associated with the COVID-19 pandemic. In particular, it seeks to assess how changes in consumer patterns might have affected (consumer perceptions of) food waste.

In fact, the pandemic, with its economic and social implications, highlighted the urgent need for more sustainable and less impactful practices of food production and consumption (Boyacı-Gündüz et al., 2021). COVID-19 first emerged in China at the end of December 2019, before quickly spreading across the globe and escalating to a pandemic, as officially declared by the World Health Organization (WHO, 2020).¹ While research was underway to develop effective vaccines, many countries adopted containment and lockdown measures to prevent the spread of the virus (Nicola et al., 2020). In most cases, these measures prohibited individuals from leaving their home for any reason, except to meet basic needs (e.g., to purchase food or access medical care), and urged firms to accommodate teleworking, where possible. In developing countries that relied on seasonal workers in the food sector, such containment measures translated to labour shortages (Aday & Aday, 2020; Blazy et al., 2021; Cariappa et al., 2021; Farrell et al., 2020; Popescu & Popescu, 2021). Moreover, the measures also had a negative impact on farmers' ability to sell crops and livestock products, resulting in a reduction in daily wages and dietary diversity (Jaacks et al., 2021).

The public health measures highly impacted not only social behaviour, but also consumption and spending behaviours, especially in relation to food. In particular, consumer behaviour changes were linked to altered daily habits and a sense of uncertainty in relation to food (Borsellino et al., 2020). Fear of food scarcity led to panic behaviour, including panic buying and stockpiling (Borsellino et al., 2020; Nicola et al., 2020, p. 190). Interestingly, this pattern was mostly noted in high-income countries (i.e., Italy and the United States; Pappalardo et al., 2020; Principato et al., 2020; Roe et al., 2020), as well as the countries that were most strongly impacted by the virus at the start of the global outbreak (Galanakis, 2020); in contrast, there were mixed reports of these behaviours in low- and medium-income countries (Ben Hassen et al., 2020; Heikal Ismail et al., 2020). Additionally, growing food insecurity was registered in specific minority

groups – many of which had already been suffering from this at a high level (John-Henderson et al., 2022).

These changes in consumer behaviour resulted in significant growth in the grocery retail sector, which could not always meet consumer demand (Aday & Aday, 2020). Furthermore, the pandemic also resulted in greater food delivery (Chen et al., 2021; Filimonau, 2020; Li et al., 2020), which increased the generation of plastic waste through packaging (Liu et al., 2021). This growth in food delivery and online meal ordering underlined the need to rethink traditional modes of production, processing, and distribution, to achieve more sustainable packaging based on principles of circularity (Kochanska et al., 2021). In parallel with the changes in consumer behaviour, traditional modes of production were subject to shocks, due to the lockdown measures and the associated economic crisis (Aldaco et al., 2020; Nicola et al., 2020). Scholars have proposed that the pandemic may act as a new divide and a trigger for the adoption of more sustainable practices, thereby contributing to the creation of a more resilient food system (Amicarelli & Bux, 2020; Borsellino et al., 2020). Indeed, crises such as the COVID-19 pandemic may enhance innovation and resilience throughout the entire food supply chain, including agricultural (Heck et al., 2020) and industrial processes (Kochanska et al., 2021).

The remainder of this paper is structured as follows. First, the methodology of the review is presented. Subsequently, the systematic literature review illustrates how scholars have investigated the effects of the COVID-19 pandemic on food waste, and discusses the main findings according to broad categories of actors. Following this, the results are presented. Finally, key changes in consumer behaviour and the food supply chain in relation to food waste, as provoked by the pandemic, are discussed. The discussion also addresses proposed mitigation strategies and policy actions, as well as implications for research and policy.

2 Methodology

The analysis is rooted in a systematic literature review, which refers to 'a review of a clearly formulated question that uses systematic and explicit methods to identify, select, and critically appraise relevant research, and to collect and analyse data from the studies that are included in the review' (Moher et al., 2009, p. 1). The review aimed at providing a comprehensive critical review of the literature on the selected topic, via a clear method of analysis. Specifically, the selection of relevant papers followed the PRISMA protocol, which defines a particular flow of information across research stages (i.e., identification, screening, eligibility, inclusion) (Moher et al., 2009).

¹ WHO Press release, March 11, 2020. Available at: <https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020>

2.1 Identification

Starting with identification, the search for publications was initiated by a query search of titles, abstracts, and keywords in an electronic database of scholarly publications (i.e., Scopus), using the following search terms: (food AND loss AND waste AND covid), (food AND waste AND lock-down), (food AND waste AND covid), and (food AND loss AND covid). Considering the strict topicality of the subject, the publication period was limited to the years 2020–2022. Ultimately, the identification stage returned 400 publications. This set was then reduced to 352, following the elimination of duplicates (performed through Microsoft Excel).

The above-described search targeted only the white literature, thus excluding the grey literature, for a range of reasons. First, grey literature is not always subject to peer review and standard bibliographical checks (Mahood et al., 2013). Furthermore, compared to peer-reviewed publications, grey literature does not always include a thorough description of the methodology performed; instead, it tends to concentrate on the results (Adams et al., 2016). Finally, the inclusion of grey literature can pose a burden on time, considering the length of the publications, which typically exceeds the standard page constraints set by journals (Mahood et al., 2013). However, while grey publications have been traditionally excluded from systematic reviews due to their reduced accessibility (as they are not generally included in databases and libraries), they are becoming increasingly incorporated (Mahood et al., 2013). Indeed, given the advantages of including grey literature (Mahood et al., 2013; Paez, 2017; Pappas & Williams, 2011), future developments of this research might extend the review along these lines. Among the main advantages of including grey publications is the fact that fewer publication biases are observed in this literature, which tends to be broader and more balanced in scope (Mahood et al., 2013).

2.2 Screening

The study screening and selection was based on titles and abstracts. In this stage, the abstracts of the 352 publications identified in the previous stage were manually screened for the following exclusionary criteria: (i) not belonging to the social sciences (i.e., many of the publications regarded the medical and chemical fields); (ii) not discussing the issue of food waste in connection with the COVID-19 pandemic; (iii) addressing other food issues, without specifically focusing on food waste; (iv) addressing only issues related to waste or waste management; (v) not containing enough information in the abstract to confirm the relevance of the study to food waste; (vi) not being available as a full text; and (vii) dealing with mitigation strategies instead of the causes for

food waste due to the pandemic. This process resulted in the selection of 43 publications.

2.3 Eligibility and included papers

Subsequently, the full text of each publication was examined to determine its eligibility and relevance to the present research question. The eligibility criteria were as follows: (i) addressing the effects of the COVID-19 pandemic on food waste, independently of the food supply chain; (ii) discussing changes in consumer perceptions of food waste generation; and (iii) addressing the topic of food waste in relation to the pandemic thoroughly, rather than mentioning it as a brief aside.

Furthermore, publications were categorised according to two themes, as reflected in the results and the discussion: studies focused on consumer behaviour (particularly consumer perceptions of food waste) and studies focused on changes in the food supply chain (particularly within pre-consumption stages). Table 1 depicts the geographical area of the research on consumer behaviour, while Table 2 describes the geographical area of the research related to the food supply chain.

Of note, the majority of the papers that were selected and reviewed dealt with consumer food waste, which suggests the need for a methodological specification. Among the total set of papers that focused on consumer behaviour, only very few were based on quantitative analysis, including waste compositional analysis (Heikal Ismail et al., 2020; Kubíčková et al., 2021); the remainder were based on questionnaires and self-reports.

2.4 Research question

This paper seeks to examine the effects of the COVID-19 pandemic on the generation of food waste in the food supply chain and changes in consumer perceptions regarding food waste and food-related behaviour.

This research question was based on observed interdependencies in the food sector (Aldaco et al., 2020; Strotmann et al., 2021), as well as an assumption that COVID-19 may have triggered changes for conventional actors in the food system, while also providing opportunities for alternative practices. In particular, the role of crises in fostering behavioural changes related to food has been discussed in previous studies in Greece (Abeliotis et al., 2014) and Italy (Martinengo, 2014), in connection with economic recessions (Borsellino et al., 2020). For the purposes of this paper, the changes considered are those that were provoked by the pandemic and related to alternative practices of actors in relation to food waste. A secondary aim was to observe whether

Table 1 Geographical region of the consumer-focused studies

Consumer-focused study	Geographical area
Heikal Ismail et al., 2020	Malaysia
Jribi et al., 2020	Tunisia
Amicarelli et al., 2021	Apulia (Italy)
Vidal-Mones et al., 2021	Spain
Scacchi et al., 2021	Italy
Vargas-Lopez et al., 2021	Mexico
Brizi & Biraglia, 2021	India and the United States
Pappalardo et al., 2020	Italy
Borsellino et al., 2020	-
Principato et al., 2020	Italy
Pires et al., 2021	Portugal
Ben Hassen et al., 2020	Qatar
Qian et al., 2020	Japan
Amicarelli & Bux, 2020	Italy
Babbitt et al., 2021	New York State (United States)
Burlea-Schiopoui et al., 2021	Romania
Cosgrove et al., 2021	United States
Rodgers et al., 2021	United States and Italy
Roe et al., 2020	United States
Scharadin et al., 2021	-
Schmitt et al., 2021	Brazil
Chen et al., 2021	China
Ben Hassen et al., 2021	Russia
Kubíčková et al., 2021	Czech Republic
Alazaiza et al., 2022	Oman
Muresan et al., 2022	Romania
Cequea et al., 2021	Peru and Brazil
Liu et al., 2021	Thailand
Music et al., 2021	Canada
Sharp et al., 2021	New Zealand
Amuakwa-Mensah et al., 2021	12 sub-Saharan countries
Berjan et al., 2021	Serbia
Bogevska et al., 2021	North Macedonia
Everitt et al., 2021	London (Ontario), Canada

the lockdowns associated with the pandemic encouraged lifestyle changes that may have destabilised conventional and unsustainable patterns.

3 Systematic literature review

Recently, the global challenge of food waste has attracted increased attention from scholars, in light of growing concerns over environmental issues. This trend was particularly pronounced during the pandemic, considering the significant impact of COVID-19 on all aspects of human life, including food behaviours (Aday & Aday, 2020; Borsellino et al.,

Table 2 Geographical region of the supply chain-focused studies

Supply chain-focused study	Geographical area
Blazy et al., 2021	Caribbean
Boyacı-Gündüz et al., 2021	
Aldaco et al., 2020	Spain
Filimonau, 2021	-
Galanakis, 2020	-
Rejeb et al., 2020	-
Di Marcantonio et al., 2021	European Union
Cariappa et al., 2021	India
Strotmann et al., 2021	Germany

2020). As noted, food waste is relevant to all phases of the food supply chain, from production to consumption (UNEP, 2021). Likewise, the pandemic is likely to have affected the generation of food waste at all stages. Therefore, this paper analyses the literature on the impact of the pandemic on the generation of food waste in the food supply chain. While the primary focus is on consumer perceptions of behavioural changes, studies of the supply chain are also considered.

The findings are described in two sections: one reviewing consumer-focused studies and a second describing studies focused on other actors in the food supply chain. Subsequently, a critical discussion of the findings is provided, analysing the topical points of the articles.

3.1 Consumer-focused studies

Consumer behaviour is particularly relevant to food waste, considering both the high proportion of consumer food waste within the total quantity of food waste (i.e., 61% of the 931 million tonnes of food waste in 2019; UNEP, 2021) and the even distribution of consumer food waste across countries with different income levels (UNEP, 2021) – a finding that counters previous evidence of an uneven distribution of food waste along the value chain between high- and low-income countries (Parfitt et al., 2010). Consumer food waste may be influenced by a variety of factors, including age, gender, income, household composition, and education (Di Talia et al., 2018). Considering the significant impact of the pandemic on all spheres of human life and lifestyle habits, researchers have tried to investigate its specific effect on consumer behaviour with respect to food waste (Aday & Aday, 2020; Jribi et al., 2020; Principato et al., 2020). Therefore, our general aim was to outline perceived changes and new practices due to the pandemic, which impacted (positively or negatively) food waste generation at a household or individual level.

The following factors were investigated in the selected publications:

- *Inner factors*: Inner factors describe socio-demographic and psychological variables. In the studies, different associations were drawn between demographic variables (e.g., gender, age, provenance, income, number of household members, education) and food waste production, showing that these variables define the basic circumstances that drive consumer choice. In particular, gender and age (Berjan et al., 2021; Brizi & Biraglia, 2021; Burlea-Schiopoui et al., 2021; Chen et al., 2021; Cosgrove et al., 2021; Principato et al., 2020; Qian et al., 2020; Vidal-Mones et al., 2021), level of education (Jribi et al., 2020), income and relative change in income (Heikal Ismail et al., 2020; Jribi et al., 2020; Rodgers et al., 2021; Vargas-Lopez et al., 2021), employment (Scacchi et al., 2021; Scharadin et al., 2021), and number of household members (Everitt et al., 2021; Pappalardo et al., 2020; Qian et al., 2020; Vidal-Mones et al., 2021) were the most debated factors, and shown to be significantly associated with food waste during the pandemic (Amicarelli et al., 2021; Muresan et al., 2022). Most studies highlighted the lower volume of food waste generated by women, older people, and people with low income.
- *Economic factors*: Economic factors can be defined as external factors that relate to the economic context in which consumers make purchases. Primarily, the studies investigated the economic factor of food price changes, highlighting the influence of these changes on consumer choice (Babbitt et al., 2021; Cequea et al., 2021; Qian et al., 2020; Roe et al., 2020; Schmitt et al., 2021; Sharp et al., 2021).
- *Behavioural factors*: In the reviewed papers, behavioural factors tended to relate to food purchasing, preparation, and management. All of the papers highlighted the pandemic's significant alteration of these behaviours, which was shown to change the production of food waste in most cases (Alazaiza et al., 2022; Amicarelli & Bux, 2020; Amuakwa-Mensah et al., 2021; Babbitt et al., 2021; Ben Hassen et al., 2020, 2021; Borsellino et al., 2020; Kubíčková et al., 2021; Liu et al., 2021; Pires et al., 2021), though with some exceptions (Bogevska et al., 2021; Music et al., 2021).

Of note, the publications were classified into these sections for purely organisational reasons. Otherwise, they generally focused on a combination of these elements, highlighting the interconnections between socio-demographic, economic, and behavioural components in contributing to consumer behaviour.

Vidal-Mones et al. (2021), after discovering that the majority of participants reported a consistent amount of

food waste during the pandemic relative to pre-pandemic levels, highlighted the role of age, gender, and household size in relation to food waste. In fact, the authors found that household food waste increased in line with age up to the age of 65 years, when it began to decrease. Furthermore, men were shown to waste more than women, and larger households to waste more than smaller households (Vidal-Mones et al., 2021). The authors also found that changes in employment had a noticeable effect on food waste. These results are partially aligned with the findings of Brizi and Biraglia (2021), who emphasised patterns related to gender and provenance, as well as the psychological factors behind food choices (i.e., a need for cognitive closure, to counteract the ambiguity and confusion caused by the pandemic). Furthermore, Principato et al. (2020) emphasised patterns related to age, noting significantly reduced food waste among younger generations during the pandemic. The authors suggested that, when people have more time to cook and manage their meals, their production of food waste is significantly reduced; this effect may be particularly pronounced in combination with food management strategies, such as the use of shopping lists.

Similarly, Burlea-Schiopoui et al. (2021) highlighted a growing concern among young people regarding food waste, in connection with environmental concerns. According to the authors, these concerns were enhanced by the pandemic, resulting in an adaptation of food shopping practices to reduce food waste. However, these findings stand in contrast to those of Qian et al. (2020) and Cosgrove et al. (2021). Qian et al. (2020) concentrated on the production of food waste in regions of Japan that were highly impacted by the pandemic. Besides noting a greater awareness of food waste due to positive behavioural changes resulting from the pandemic, the authors highlighted greater concern for this issue among older people, in particular. Cosgrove et al. (2021), while confirming these results, suggested that food waste produced by younger generations may relate to fewer responsibilities in food preparation and procurement, relative to older generations, who may have also experienced greater economic challenges during the pandemic. Chen et al. (2021) and Berjan et al. (2021) highlighted the greater responsibility of older people regarding food waste. In parallel, Chen et al. (2021) noted a sharp increase in online food purchases, fewer trips to the grocery store, and the purchase of extra food to compensate for fewer trips; while Berjan et al. (2021) reported better food practices, such as meal planning and the purchase of lesser quantities of food. These findings align with those of Jribi et al. (2020), who endorsed the positive influence of COVID-19 on consumer behaviour towards food waste. In addition, the authors examined educational level as well as age and gender, finding that, relative to less educated people, university-educated people tended

to adopt more sustainable practices, such as keeping and reusing leftovers. According to the authors, this tendency was also associated with a loss in income during the pandemic, which increased consumer willingness to minimise food waste.

The relevance of income was also highlighted by Heikal Ismail et al. (2020), who observed the interlink between uncertainty related to income and job security and greater attention to and valuation of food, resulting in a decrease in food waste. Finally, the effect of income on consumer choice during the pandemic was discussed by Vargas-Lopez et al. (2021), who observed that wealthier families were more likely to waste food during the health crisis, as well as an overall slight decrease in food waste in Mexico during this time.

Besides income insecurity, employment insecurity was also found to drive consumer behaviour during the pandemic (Roe et al., 2020; Scharadin et al., 2021). In fact, Scacchi et al. (2021) noted a reduction in food waste due to the effects of the lockdown on job security, leading consumers to both reduce unnecessary food shopping and pay greater attention to the economic impact of food waste. In addition, the effect of the pandemic on consumers' financial circumstances was noted by Rodgers et al. (2021), who, in their cross-cultural survey (comparing American and Italian consumers), also emphasised the role of cultural factors in determining food choices, with a range of effects on food waste. In fact, although decreased food waste was reported in both countries, American consumers reported a greater decrease compared to Italian consumers, probably due to the greater presence of sustainable practices (e.g., cooking meals at home) and the lower baseline level of food waste in pre-pandemic Italy, compared to the United States (Rodgers et al., 2021). Furthermore, Vidal-Mones et al. (2021) and Everitt et al. (2021) observed food waste to increase in parallel with the number of people in the household, while Qian et al. (2020) highlighted a greater consciousness regarding food waste among smaller families. Interestingly, an opposite trend was noted by Pappalardo et al. (2020), who reported better food management strategies (e.g., the reutilisation of leftovers) in larger families, with the result of decreasing the volume of food waste. In addition, Everitt et al. (2021) underlined the role of housing tenure and the neighbourhood food environment (e.g., proximity to grocery stores and restaurants) in determining household food waste.

Significantly, a combination of all of these socio-demographic factors was proposed by Muresan et al. (2022) and Amicarelli et al. (2021), with the aim of identifying clusters of food wasters during the pandemic in Romania and a region of Italy, respectively. Both studies described three types of wasters, defined by combinations of the previously mentioned characteristics. Specifically, they partly confirmed patterns associated with: gender (Muresan et al.,

2022), observing a higher reported percentage of food waste among men (Amicarelli et al., 2021); and age, noting the greater food waste production of younger generations (in contrast with their greater awareness of the issue), due to their irresponsible shopping and preparation habits (thereby confirming the observations of Cosgrove et al. (2021)). Their findings also aligned with the previously noted associations between food waste and gender, showing lower food waste production by women, whose perceptions of food changed during the pandemic; and education, reporting a lower volume of food waste among highly educated people, which did not match their level of awareness. Amicarelli et al. (2021) observed that awareness of the environmental implications of food waste did not imply behaviour aimed at reducing it. In fact, the authors discussed the paradox of so-called 'green wasters', who, despite being aware of environmental issues, do not translate their awareness into practice, due to their lack of responsibility in food activities. This also highlights the paradox of time management, in contrast with the findings of Principato et al. (2020): it seems that, although young people were forced to stay at home during the pandemic, their greater availability of time did not result in their adoption of more sustainable food practices.

Among the investigated economic factors, food prices were found to significantly contribute to consumer choices concerning food (Babbitt et al., 2021; Cequea et al., 2021; Qian et al., 2020). In Japan, an association was observed between regions that were most significantly affected by the pandemic and higher food prices (Qian et al., 2020). This relation may be due, in part, to the higher prevalence of the virus in highly populated areas, which already presented with higher prices. However, people in the highly affected regions seemed to adopt more sustainable practices (e.g., food planning), compared to people in less-affected regions. A similar pattern was confirmed by Babbitt et al. (2021), who surveyed consumer behaviour in New York state, providing interesting results for another highly populated area. According to the authors, higher food prices were noted by consumers, who were thus oriented to adopt more sustainable food practices. This study also aligned with previously mentioned trends, such as consumers' improved food preparation and conservation skills in light of their increased time spent cooking – which eventually led, together with other sustainable practices, to a reduction in food waste. Similarly, the association between higher prices and reduced household food waste was noted by Roe et al. (2020), who highlighted enhanced sustainable practices due to the effects of the pandemic; and Schmitt et al. (2021), who registered increased food expenditure among Brazilian customers in relation to higher food prices. The latter authors additionally noted that Brazilian consumers tended to avoid food waste even prior to the pandemic, and the pandemic enhanced their efforts toward this end. Furthermore, another study conducted in

Brazil (Cequea et al., 2021), seeking to compare Brazilian and Peruvian changes in food behaviour during the pandemic, underlined the employment of food management practices in connection with concerns about food practices and the price of food. In contrast, a study conducted in New Zealand (Sharp et al., 2021) showed that people who struggled to acquire money for food were more likely to waste food during the lockdown compared to the pre-pandemic era. This finding contradicts studies noting the relevance of socio-economic and financial factors in reducing consumer food waste (Jribi et al., 2020). Sharp et al. (2021) proposed that difficulties related to insufficient and inefficient food aid during the pandemic, as well as additional stress due to the health emergency, might explain their unexpected finding, but more research is needed to confirm this claim.

Lastly, behavioural factors were the most discussed and explored issues, since they have the most direct effect on food waste. Overall, the abovementioned publications studied behaviours related to food purchasing, preparation, and management, highlighting significant changes due to the pandemic. Studies showed that the pandemic and its associated lockdowns (particularly in the initial phases) significantly impacted consumer behaviour, directing it toward more sustainable practices. As mentioned above, more time spent at home was shown to support better food practices, leading to a decrease in food waste (Amicarelli & Bux, 2020; Pires et al., 2021). Such practices included reusing leftovers, organising food according to expiration date, and using shopping lists (Ben Hassen et al., 2021; Bogevska et al., 2021; Kubíčková et al., 2021; Pires et al., 2021; Qian et al., 2020). In addition, decreased shopping frequency was commonly observed, in connection with both governmental restrictions and health concerns (Chen et al., 2021; Vidal-Mones et al., 2021). This was matched by a greater quantity of food purchased on each trip (Ben Hassen et al., 2021; Bogevska et al., 2021; Chen et al., 2021). In parallel, two concurrent tendencies were examined: on the one hand, some people seemed to increase their interest in homegrown food (Roe et al., 2020) and food grown locally (Scacchi et al., 2021; Vidal-Mones et al., 2021), while avoiding supermarkets (Rodgers et al., 2021); on the other hand, some consumers increasingly purchased food at supermarkets, for safety reasons (Jribi et al., 2020).

One of the most investigated trends was the growth in online grocery shopping and meal delivery (Babbitt et al., 2021; Ben Hassen et al., 2020; Borsellino et al., 2020; Chen et al., 2021; Liu et al., 2021; Roe et al., 2020). In particular, Chen et al. (2021) noted that people over 35 years of age increased the frequency with which they shopped for food online during the pandemic, while younger people showed a preference for a particular form of online food purchasing called community-based online group grocery ordering (CoGGO). Interestingly, Schmitt et al. (2021), Cequea et al.

(2021), and Pires et al. (2021), in their respective studies on Brazilian, Brazilian and Peruvian, and Portuguese consumers, did not observe an increase in online food buying and delivery, in contrast with many other studies – perhaps due to cultural reasons. Of interest, the adoption of sustainable food management practices was not always significantly associated with a reduction in food waste (Music et al., 2021). In fact, Music et al. (2021) argued that, although consumers employed new management behaviours during the pandemic (e.g., eating more leftovers), these behaviours did not result in a significant reduction in food waste, perhaps due to poor planning (Music et al., 2021).

Moreover, while some publications highlighted the presence of panic buying behaviour (Amuakwa-Mensah et al., 2021; Principato et al., 2020), at least in the initial phases of the pandemic, others did not observe this phenomenon (Ben Hassen et al., 2020; Heikal Ismail et al., 2020). Amuakwa-Mensah (2021) discussed a correlation between stockpiling behaviour and females (Amuakwa-Mensah et al., 2021), who were noted as more likely to adopt this behaviour in an effort to gain a sense of security in response to the pandemic, as well as to reduce shopping frequency. They also observed such behaviour in people who did not have food scarcity worries, as they perceived themselves to have sufficient money (Amuakwa-Mensah et al., 2021). Of note, even in the context of panic buying, which led to an initial increase in food purchasing (Scacchi et al., 2021), the amount of food waste sometimes decreased, in contrast to what one would assume (Pappalardo et al., 2020). This decrease was observed even in countries such as Brazil, where the avoidance of food waste was already a priority, which the pandemic managed to enhance (Schmitt et al., 2021). In contrast, other studies (Alazaiza et al., 2022; Berjan S. et al., 2021; Liu et al., 2021) reported greater food waste in connection with increased food purchased online and more cooking at home (Alazaiza et al., 2022), as well as with increased online shopping and food delivery (Liu et al., 2021). In particular, the latter was linked with an inability to predict the right amount of food to order, and with panic buying (Berjan et al., 2021).

Lastly, it should be noted that, although several scholars emphasised the role of the pandemic in both increasing consumer awareness of food waste (Amicarelli & Bux, 2020; Borsellino et al., 2020; Jribi et al., 2020; Pappalardo et al., 2020; Qian et al., 2020) and encouraging the adoption of more sustainable practices to reduce food waste, different strategies emerged according to the socio-demographic and economic context. In general, scholars observed that food waste prevention strategies were primarily motivated by socio-economic issues connected to the pandemic, rather than environmental concerns (Babbitt et al., 2021; Cequea et al., 2021; Jribi et al., 2020). Figure 1 summarises the main findings of this section, highlighting the positive and

Fig. 1 Impacts on consumer food waste behaviours during the pandemic

	<i>Positive impact on food waste</i>	<i>Negative impact on food waste</i>
<i>Inner factors</i>	<ul style="list-style-type: none"> - Role of age, gender, household size, and education: younger people, people older than 65 years, women, and highly educated people showed greater concern over food waste. Smaller households produced less food waste compared to bigger households - Employment insecurity had a positive influence on consumer choice - Cultural factors contributed to consumer choice 	<ul style="list-style-type: none"> - Role of age, gender, household size, and education: older people (up to the age of 65 years), men, and less educated people were not focused on food waste - Larger households produced more food waste
<i>Economic factors</i>	<ul style="list-style-type: none"> - Income insecurity - Higher food prices 	
<i>Behavioural factors</i>	<ul style="list-style-type: none"> - Shift to more sustainable practices with respect to food purchasing, preparation, and management, such as the use of shopping lists, the reuse of leftovers, and increased attention to storage 	<ul style="list-style-type: none"> - Food delivery had a negative impact due to excessive flexibility and discounts - Panic buying in the early stages of the pandemic

negative perceived impacts on consumer behaviour related to food waste during the pandemic.

3.2 Food supply chain–focused studies

Besides impacting consumption patterns, the pandemic also affected the entire food supply chain, leading to widespread disruptions. As previously stated, all phases of the food supply chain generate food waste, according to different factors. Some scholars studied the effects of the pandemic on the production of waste in all phases of the food supply chain, from production to consumption (Aldaco et al., 2020; Blazy et al., 2021; Boyacı-Gündüz et al., 2021; Cariappa et al., 2021; Di Marcantonio et al., 2021; Galanakis, 2020; Rejeb et al., 2020). Other scholars focused on particular stages of the supply chain (with the majority focusing on the consumption stage), or specific sectors (e.g., hospitality), reflecting on both the impact of the pandemic on food waste and future strategies to increase resilience (Filimonau, 2021; Strotmann et al., 2021).

The papers in this category dealt with actors in various phases of the food supply chain, ranging from farmers and producers to consumers (who were also analysed in the previous section). In addition, they investigated possible strategies to target the vulnerabilities of the food system that the pandemic exposed, addressing both actors and policymakers. Of interest, these publications generally invoked a transition toward a more resilient and sustainable food system, in light of increasing environmental challenges. In addition, the publications commonly observed disruptions in the entire

food supply chain, due to the pandemic. Blazy et al. (2021), investigating the effects of COVID-19 on the food system in the Caribbean, highlighted the role of the pandemic in worsening the condition of Caribbean agriculture, which had already been presenting with structural difficulties and food insecurity, due to environmentally-caused food shortages and political instability (Blazy et al., 2021). On the other hand, the authors observed that the pandemic encouraged changes in food behaviour, resulting in a reduction in food waste and increased awareness of the relevance of the agricultural food sector and local products (Blazy et al., 2021). These findings were confirmed by Rejeb et al. (2020), who observed that, following an initial phase of panic purchasing, the pandemic enhanced consumer awareness of both food waste and local and homegrown food. Similar effects were noted by Aldaco et al. (2020), who emphasised that changes in consumption during the lockdown encouraged better food management practices. Taking into account the decrease in extra-domestic consumption, overall food waste was calculated to be the same as in pre-pandemic times; accordingly, consumer food waste was considered to have increased. Most significantly, the authors observed a ripple effect created by the disruptions in consumer behaviour, leading to an upstream diffusion of disruptions in earlier phases of the supply chain (Aldaco et al., 2020). Moreover, Cariappa et al. (2021) reported a lack of supply and labour shortages in the initial stages of the food supply chain, due to lockdown measures. The authors also noted that the partial or total closure of markets negatively influenced the availability of labour, forcing farmers to dispose of their

stock at low prices (Cariappa et al., 2021). These supply-side changes also forced retailers to dispose of part of their stock (Cariappa et al., 2021), and canteens and restaurants to close (Aldaco et al., 2020), emphasising the need for greater integration in the supply chain.

Indeed, a call for greater integration among stakeholders throughout the supply chain was put forward by Galanakis (2020), who, while highlighting the disruption in food supplies and panic buying trends, suggested that technological tools should be applied to redistribute food and improve communication between suppliers and buyers. In addition, Galanakis (2020) highlighted that the employment of such technologies to improve farming, post-harvest, storage, and transportation could ultimately reduce food waste. Di Marcantonio et al. (2021) also identified the role of technological tools in influencing the generation of food waste, alongside sales channel disruptions and changes in public policy. In particular, the authors noted that technological tools that improve firms' ability to adapt to new societal dynamics and public policies that mitigate shocks in the food supply chain (which have a negative impact on food waste) may contribute to decreasing food waste.

Furthermore, the redistribution of food as a strategy for reducing food waste was emphasised by Boyacı-Gündüz et al. (2021), who analysed the activities of charities and community-based groups that collected and distributed food from canteens, restaurants, and catering businesses. Such activities were observed to not only reduce food waste, but also to improve food security by helping those in need. Besides providing insight into food waste mitigation strategies, Boyacı-Gündüz et al. (2021) also provided a clear picture of the interrelated effects of the pandemic on the food system, which included input and labour shortages, demand shocks due to lockdown measures, food waste in production and processing, panic buying, and increased online grocery shopping and delivery (Boyacı-Gündüz et al., 2021).

Finally, Filimonau (2021) explored the effect of the pandemic on food waste in the hospitality sector. The sudden closure of many hospitality establishments led to a large increase in the quantity of unused food. The author observed that, although some operators froze food, donated it to staff or food banks, or used it to prepare meals for healthcare workers, a large quantity of food was wasted, also due to a lack of widespread storage facilities. In addition, the increase in online food delivery was considered to have produced food waste, as excessive discounts and flexibility (i.e., with consumers given the option to cancel orders at the last minute) resulted in an excess of food being ordered (Filimonau, 2021). In this context, a ripple effect was once again observed. In fact, Filimonau (2021) highlighted the difficulties faced by not only food producers (e.g., farmers), but also suppliers, in managing food surpluses despite reduced operational capacity due to lockdown measures. This mismatch between operational capacity and food

stock, in conjunction with the impossibility of redistributing any food surplus, resulted in food waste. The study identified possible solutions to reduce food waste in the hospitality sector, including enhanced collaboration with alternative food networks to redistribute food and increased participation in the short food supply chain (Filimonau, 2021).

Another study identified poor management planning (e.g., overproduction) due to uncertainty over demand during the pandemic as particularly relevant to food waste (Strotmann et al., 2021). In contrast, good food management practices were identified as menu and production planning, which included targeted food purchasing, menu reduction, pre-ordering, and, once again, the use of technological tools such as Too Good To Go (2021), (Strotmann et al., 2021). The study also provided insights relevant to earlier stages in the food supply chain, underlining interdependencies in the food sector. The authors noted that, as a result of these interdependencies, primary production generated greater food waste during the pandemic, due to a ripple effect (Strotmann et al., 2021). In addition, they highlighted some common consumer practices that were described in the previous section, such as overstocking and overbuying, as well as grocery planning and more time spent cooking. In particular, the study identified increased planning on the part of consumers, which, paired with good retail management practices, could have reduced food waste (Strotmann et al., 2021) (Fig. 2).

4 Discussion and policy implications

Prior to discussing the results of the abovementioned papers, the methodology of the studies should be taken into account. As mentioned previously, the majority of the studies on consumer behaviour relied on self-report surveys and questionnaires, while only a very few presented quantitative analyses of waste (Heikal Ismail et al., 2020; Kubíčková et al., 2021). While surveys and questionnaires are unable to provide accurate estimates of food waste at a household level, they can provide insight into consumer behaviour that can be used to guide the development of targeted strategies (UNEP, 2021). More specifically, they can provide useful information on consumers' perceptions of their own behaviour and the resulting food waste. On the other hand, waste compositional analysis is needed to provide accurate data regarding the amount of food waste, as well as the types and categories of food wasted (UNEP, 2021). In some cases, more than one methodology is needed to quantify actual food waste (UNEP, 2021).

Consequently, the reviewed papers suggest that the pandemic changed consumers' perceptions regarding food waste and food-related behaviours, and also impacted the perceptions of actors in earlier stages of the food supply chain. These different implications will now be discussed,

Fig. 2 Summary of changes in the food supply chain and mitigation strategies, as suggested by the food supply chain–focused studies

	<i>Positive impact on food waste</i>	<i>Negative impact on food waste</i>
<i>Changes in the food supply chain</i>	<ul style="list-style-type: none"> - Collection and redistribution of food by charities and community-based groups reduced both food waste and food insecurity - Call for greater integration of stakeholders and supply chain actors to respond to crises - Call for greater application of technological tools to manage farming, post-harvest, storage, and transportation 	<ul style="list-style-type: none"> - Disruptions in the entire food supply chain - Farmer and supplier difficulties in dealing with surplus food - Shortages of input and labour, which reduced operational capacity - Ripple effect of disruptions in consumer behaviour led to upstream diffusion in earlier stages of the food supply chain - Shock in demand due to lockdown measures - Supply-side changes, including the closure of local markets, canteens, and restaurants, resulted in food waste

to provide a clearer picture of the generation of food waste within the entire food supply chain, both during and after the pandemic. The reviewed papers suggest that the pandemic triggered certain social lock-ins that stabilised the situation and blocked the emergence of innovations. However, diminished resistance from conventional actors, resulting in a change in lifestyle and habits, may have opened space for alternative practices in the agri-food sector, in support of greater sustainability. This role of the pandemic in stimulating change in traditional actors was mostly confirmed by the literature review.

Figure 3 shows, in different colours, changes in the upstream and downstream flows of the food supply chain due to the pandemic, which had positive, negative, and mixed impacts on food waste. The downstream flow was mainly associated with positive behavioural changes that reduced food waste, apart from panic buying (which had a negative effect on food waste) and food delivery (which had a mixed impact on food waste).

4.1 Discussion and policy with respect to consumption

Starting with the consumer-focused studies, a range of assertions can be made. First, while acknowledging the methodological limitations specified in the previous section, the papers showed that the pandemic deeply altered consumers' perceptions of food behaviours and habits (e.g., food purchasing, preparation, and management), thereby shifting consumers toward more sustainable

practices. Food shopping frequency generally reduced in most of the countries reviewed (Bogevska et al., 2021; Vidal-Mones et al., 2021). In addition, study samples reported a renewed interest in local and neighbourhood shops and a desire to avoid large places of contact (also due to restrictions in movement and long queues at supermarkets), which also led to an increase in online shopping (Scacchi et al., 2021). However, in some countries, supermarkets were identified as primary sites for food shopping, due to safety concerns (Jribi et al., 2020); this is because supermarkets implemented a series of safety measures that some customers found reassuring.

One of the most discussed consumer patterns was that of panic buying in the early stages of the pandemic; however, in later stages, increased shopping planning was observed (Amuakwa-Mensah et al., 2021; Principato et al., 2020). Panic buying was connected with a fear of food insecurity and a general feeling of uncertainty due to the pandemic, which induced some consumers to stockpile. Some studies connected this pattern with gender, and specifically a higher tendency to stockpile in women (Amuakwa-Mensah et al., 2021). Teleworking and the closure of many restaurants and bars forced workers to reduce their number of extra-domestic meals relative to the pre-pandemic era. In many cases, this triggered increased food purchasing, associated with impulse buying (Scacchi et al., 2021). Although the pandemic triggered a sudden and unprecedented disturbance in the food supply chain, a study conducted in England showed that several impacts of the pandemic could have been predicted (Parsons & Barling, 2022), including the excessive food

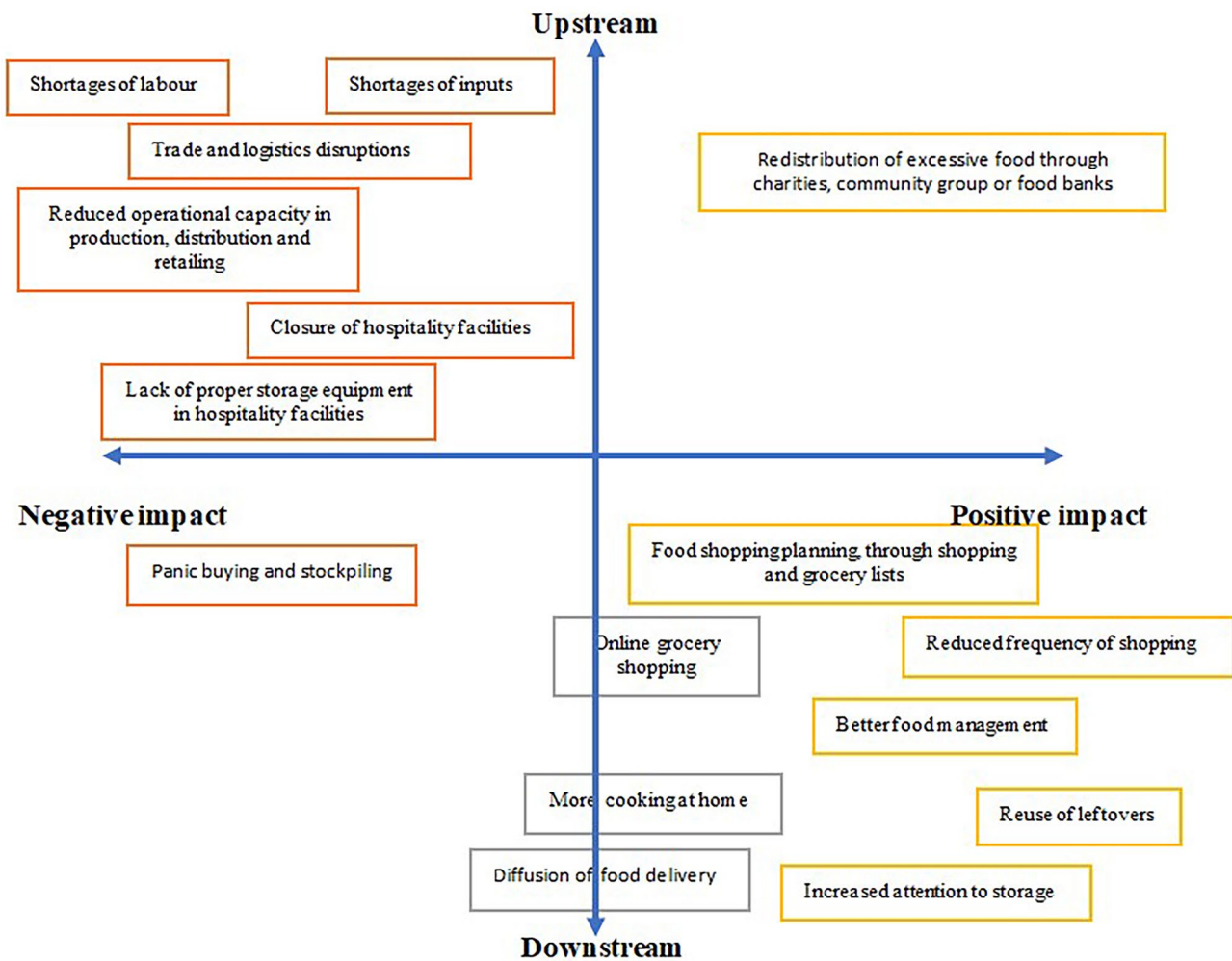


Fig. 3 Changes in and impacts to the food supply chain due to the pandemic

shopping during the lockdown, and different working patterns resulting in more time spent at home.

Consequently, it could be argued that teleworking and telestudying, paired with lockdown measures, were two factors that significantly impacted consumer behaviour during the pandemic – not only in relation to food purchases, but also with respect to food preparation and management. In fact, more time spent at home seemed to encourage a greater focus on food preparation, and improved cooking skills (Amicarelli & Bux, 2020; Babbitt et al., 2021; Berjan et al., 2021). This trend was particularly observed in countries that tended to lack these practices prior to the pandemic, such as the United States (Rodgers et al., 2021). In contrast, one study (Alazaiza et al., 2022) found an association between more time spent at home (and, by extension, more time spent cooking) and greater perceived food waste. Another study found that, during the pandemic, cooking and eating with the family became a form of home entertainment (Ben Hassen et al., 2020). Other scholars linked high levels of

cooking confidence with lower levels of food waste (Sharp et al., 2021).

The shift toward sustainable purchasing practices favoured the better use of food, as did planning behaviours such as the use of shopping lists (Kubíčková et al., 2021). Better food planning was observed to reduce food waste by minimising the purchase of surplus food that would ultimately be discarded (Jribi et al., 2020). In parallel, significant attention was devoted to the use of leftovers, the organisation of stored food according to expiration date, and more frequent checking of food freshness (Pires et al., 2021). However, several studies (Berjan et al., 2021; Filimonau, 2021; Liu et al., 2021) detected excessive food purchasing in the context of food delivery, due to difficulty determining the amount of food that was actually needed, as a source of food waste. Here, the role of policymakers and the food industry could contribute to increasing consumer knowledge of food quantity and proportions. In particular, communication initiatives could deliver key messages and suggestions relevant

to food preparation and management, such as tips for using products, enhancing cooking skills, and avoiding waste (Liu et al., 2021). In general, the studies highlighted that such initiatives should be contextual, and thus developed in relation to the different contexts associated with consumer food waste (Hebrok & Heidenstrøm, 2019). More specifically, Hebrok and Heidenstrøm (2019) proposed that any measure to reduce and prevent food waste at a consumer level should address acquisition, storage, assessment, value, and eating. Furthermore, it should aim at promoting greater flexibility in planning, buying, preparing, and eating, and increasing consumers' sense of security regarding food safety, when assessing the edibility of certain food products (Hebrok & Heidenstrøm, 2019).

Furthermore, the studies noted greater attention toward food waste among women, compared to men. More specifically, women were shown to give more attention to food preparation and management, with the result that they generated less food waste than men, during the pandemic (Amicarelli et al., 2021; Jribi et al., 2020; Muresan et al., 2022; Qian et al., 2020; Vidal-Mones et al., 2021). This finding underlines a common gender bias in households, whereby women are most often in charge of shopping and cooking. This bias was confirmed in the reviewed papers, which showed that household food preparation was more often performed by women, than by men.

The literature also revealed some paradoxical findings with respect to time and age. First, some studies found that more time spent at home did not always imply a perceived reduction in food waste (Alazaiza et al., 2022; Amicarelli et al., 2021). Second, other studies found that higher environmental awareness was not necessarily associated with sustainable food practices in younger generations, due to young people's relative irresponsibility toward food shopping and preparation (Amicarelli et al., 2021; Cosgrove et al., 2021); however, this latter finding contrasted with that of another study (Burlea-Schiopoiu et al., 2021). These paradoxes may be linked to the causes of reduced food waste during the pandemic. In fact, some studies showed that concerns over food availability, as well as health and economic concerns (but not environmental concerns), were most effective in reducing consumer food waste at this time (Cequea et al., 2021; Jribi et al., 2020). In fact, many consumers were faced with not only a fear of contagion, but also changes to their employment situation (Roe et al., 2020; Vidal-Mones et al., 2021), loss of income (Borsellino et al., 2020; Pappalardo et al., 2020), and higher prices for goods (Babbitt et al., 2021), due to supply–demand shocks; these factors may have impacted consumer behaviour more significantly than environmental concerns. However, this does not imply a lack of awareness of food waste on the part of consumers; rather, most scholars highlighted increased awareness regarding the impact of food waste and the value of food (Pappalardo et al., 2020;

Pires et al., 2021; Qian et al., 2020; Schmitt et al., 2021). Thus, consumers may have adopted more sustainable practices (and thus reduced their food waste) due to increased awareness of the economic impact of food waste, rather than environmental concerns. In addition, one of the observed drivers of the decrease in food waste during the pandemic was consumers' concern over the effects of the pandemic on waste management, which encouraged them to acquire less-perishable items (Pappalardo et al., 2020). In fact, some scholars (Cosgrove et al., 2021; Pappalardo et al., 2020) noted increased purchasing of non-perishable items (e.g., canned food, pasta, rice), which impacted the generation of food waste. In contrast, other scholars (Cosgrove et al., 2021) connected a greater purchase of perishable food (e.g., fresh fruit) to increased food waste during the pandemic. While this may have been a marginal phenomenon, the implications are worth analysing. In addition to the greater purchasing of perishable items, panic buying, which led people to stockpile food, was also identified as a factor that increased the generation of food waste (Cosgrove et al., 2021). Furthermore, additional causes of food waste, even in the context of an overall decrease, should be mentioned. Consumers indicated poor food storage and inadequate food labelling and packaging as causes of food waste during the pandemic (Berjan et al., 2021; Schmitt et al., 2021), in addition to an excessive quantity of food purchased (Alazaiza et al., 2022), in some cases paired with online shopping and delivery (Liu et al., 2021). Additionally, some scholars noted that the effect of overcooking was generally marginal, thereby confirming the importance of food preparation and management practices (Amicarelli & Bux, 2020).

The reviewed papers suggest a need for informational campaigns aimed at raising awareness of the impact of food waste, alongside those promoting better information on product shelf life and the reuse of leftovers (Jribi et al., 2020). Initiatives such as the partnership between Banco Alimentare (2020) and the food delivery company Glovo to use food based on the principle of 'food no waste' (developed on the International Day of Awareness of Food Loss and Waste, targeting SDG 12²) should be increasingly developed, not only by non-profit groups and private companies, but also by state actors. Additional campaigns should aim at encouraging good food planning practices, such as the use of grocery lists, meal planning, and the implementation of proper food storage (Principato et al., 2020). Information campaigns targeting young people should be distributed through social media, school, and other communication channels (Burlea-Schiopoiu et al., 2021). Information should also aim at increasing consumer knowledge of food

² Information available at <https://www.bancoalimentare.it/it/food-no-waste-challenge>

labelling, specifically with respect to ‘use by’ and ‘best before’ dates (Burlea-Schiopoiu et al., 2021). As a matter of fact, the deployment of educational campaigns about the meaning of labels and food safety may represent a potential strategy for mitigating consumer food waste.

The EU, which devotes great attention to food waste through the EU Green Deal and the Farm to Fork Strategy, has set out initiatives to address the issue of mislabelling, considering the impact of food labelling on consumer food waste. In particular, data marking has been targeted as a key policy, since current markers (i.e., ‘use by’ and ‘best before’ dates) often mislead consumers into not consuming a product, by implying it has expired (European Commission, 2018). According to a study published by the European Commission in 2018, 10% of EU food waste derives from data marking (European Commission, 2018). In the Farm to Fork Strategy, the European Commission set out a specific action plan to tackle the most pressing issues related to food waste in the coming years (European Commission, 2020): a revision of EU rules on date marking (i.e., ‘use by’ and ‘best before’ dates) by the end of 2022 (for which it is currently carrying out an impact assessment with consumer research); and proposed EU-level legally binding targets for food waste reduction by 2023, in line with an EU-wide monitoring tool.

Some scholars claimed that such informational and educational interventions would not be effective in sufficiently reducing food waste (Hebrok & Boks, 2017), without the support of prompts, incentives, and monetary penalties (Hebrok & Boks, 2017; Jribi et al., 2020). In fact, some studies reported that consumers would likely reduce their food waste if they were forced to pay taxes on the volume of food wasted, thus leveraging the economic inconvenience of waste (Jribi et al., 2020). Initiatives such as the so-called ‘Gadda Law’ – an Italian law against food waste – provide economic incentives for reducing food waste at the retail level; such initiatives could also be implemented to support the redistribution of food. In fact, the Gadda Law allows municipalities to reduce the waste tax paid by retailers, in proportion to the amount of food they donate (Franco et al., 2020).

4.2 Discussion and policy with respect to the food supply chain

As consumption represents only one phase of the overall food supply chain, it is worth analysing the impact of the pandemic on agri-food actors in previous stages, on the basis of the factors investigated in the reviewed studies. The studies generally agreed that the pandemic significantly altered demand, supply, distribution, consumer behaviour, and food waste (Aldaco et al., 2020; Galanakis, 2020). In addition, lockdown measures were observed to have worsened the interactions between actors in various stages of the food

supply chain, highlighting the need for greater integration (Aldaco et al., 2020). The food supply chain was subject to trade and logistics disruptions, partly due to labour shortages, in connection with lockdown measures and border closures (Boyacı-Gündüz et al., 2021; Cariappa et al., 2021; OECD, 2020a). These logistics issues impacted food distribution, which, alongside increased demand, resulted in higher prices. In fact, food logistics disruptions typically result in higher transaction costs, which, in turn, affect food prices (Rejeb et al., 2020; OECD, 2020b). Such issues may be managed through the direct intervention of policymakers, through emergency (i.e., temporary) measures (WTO, 2020). For example, during one period of lockdown, the EU addressed road transport difficulties by creating green lanes to reduce waiting times at EU internal borders, and by suspending some restrictions (e.g., driving on weekends) for road transporters (OECD, 2020a). In addition, certification procedures were reorganised to allow for the use of digital copies or scanned documents during controls (WTO, 2020).

Disturbances in the food supply chain during the pandemic were particularly unsettling in developing countries, which had pre-existing structural difficulties (Blazy et al., 2021), especially in relation to distribution and transportation. In addition, labour shortages reduced both agricultural productivity and incomes in the sector (Boyacı-Gündüz et al., 2021). Labour migrants on farms could no longer access their workplace during the lockdown, resulting in a surplus of unsold food (Cariappa et al., 2021). In this situation, developing countries, which had less developed supply chains and more labour-intensive food systems, were subject to additional struggles, also related to food security (OECD, 2020b). According to the OECD (2020a), international cooperation and intervention may be effective for preventing food crises and increasing food security in these countries. At a local level, Heck et al. (2020) highlighted that diversion to local food production may represent a possible strategy for mitigating emergency-related disruptions (e.g., the loss of export trade) during a pandemic, while also contributing to building a more resilient food system to withstand future crises.

Significantly, disruptions in production and distribution during the pandemic led to an accumulation of food items, which affected the generation of food waste in the early stages of the supply chain. This phenomenon was particularly relevant in the hospitality sector, which was highly impacted by the pandemic (Aldaco et al., 2020; Filimonau, 2021). While some establishments managed to minimise food waste through the adoption of in-house practices (e.g., storage, donation to staff), others were unable to respond due to operational and logistical issues (Filimonau, 2021). In addition, the closure of many hospitality facilities disturbed the interaction between operators and food suppliers, resulting once again in an increase in unsold products, which food

suppliers were not always able to redistribute (Cariappa et al., 2021). This phenomenon, called a ripple effect, was widely noted during the pandemic (Aldaco et al., 2020; Filimonau, 2021). A ripple effect was also triggered by disruptions in consumer behaviour, which propelled a set of disturbances upstream through the entire food supply chain (Aldaco et al., 2020). A mismatch between operational capacity (which was significantly impacted by labour shortages and other disruptions) and the amount of surplus food implied a large quantity of food waste. Furthermore, the increase in food delivery during the pandemic, as described in the previous section (Babbitt et al., 2021; Ben Hassen et al., 2020; Borsellino et al., 2020; Roe et al., 2020), also pertained to the hospitality sector. In fact, to maintain customers during the crisis, online food retailers were forced to offer significant flexibility (allowing customers to cancel orders at the last minute) and attractive discounts (Filimonau, 2021). This resulted in an excess of food orders, which led to consumer food waste and order cancellations, and subsequently operator food waste.

Disruptions in the food supply chain due to the pandemic provoked a call for greater integration among actors across the different stages. Furthermore, several strategies were developed to target food waste in response to these disruptions. One such strategy was the increased mobilisation of charities and other groups to collect and redistribute food; this had the benefit of affecting not only food waste, but also food security (Boyacı-Gündüz et al., 2021). For example, the Italian food bank Banco Alimentare (2021) partnered with the Hungarian Food Association and Sibahe Slovenska Banka Hrane, through their participation in the European Food Banks Federation, to redistribute a wide range of products through non-profit organisations in Hungary and Slovenia.³

In addition, increased participation in alternative food networks aimed at preventing food waste, while building effective relationships among food supply chain actors. Alternative food networks are built from the close interactions between actors, based on both geographical and temporal contiguity; such networks generally demonstrate high resilience and trust (Filimonau, 2021). Alternative food networks can be beneficial to the creation of short food supply chains, which are more sustainable and resilient (Filimonau, 2021). In addition, they tend to be more trusted by customers, especially in the wake of the pandemic. Food supply chains based on local production, distribution, and consumption have greater resilience to disruption, and thereby less dependence on external actors.

Some of the reviewed papers suggested that technological tools could contribute to mitigating food waste in

the supply chain (Di Marcantonio et al., 2021; Galanakis, 2020; Strotmann et al., 2021). Specifically, such tools could improve communication between suppliers and buyers. In addition, the adoption of innovative and technological tools could help firms adapt to new needs, thereby reducing levels of food waste (Di Marcantonio et al., 2021). Technology might also encourage greater integration between producers and suppliers, facilitating quick communication when there are changes in demand, and supporting forecasting and redistribution (Strotmann et al., 2021). Some software can even track the demand of specific items (i.e., in relation to stockpiling), and respond quickly. In addition, the application of digital technology to production, post-harvest, storage, and transportation could enable food loss to be mapped along the chain (Galanakis, 2020; Strotmann et al., 2021). For example, the increased diffusion of tools such as Too Good To Go (2021),⁴ which aims at reducing food waste through the sale of surplus food at end of each working day, has contributed to a reduction of food waste at a retail level.

The literature review also highlighted some traits pertaining to production and retailing that, if targeted, could contribute to a reduction in food waste. Consumer surveys reported that food is consistently wasted due to labelling and packaging (Jribi et al., 2020) that does not appropriately convey information about shelf life. In fact, during the pandemic, the misinterpretation of expiration dates was reported as a specific driver of food waste (Principato et al., 2020). The development of labels that do not confuse consumers and packaging that prolongs product shelf life is regarded as helpful for tackling food waste (WRAP, 2019). In particular, ‘use by’ labels should only be employed for safety reasons (WRAP, 2019), while ‘best before’ labels should be used for products with only a short window for consumption (WRAP, 2019). In addition, the inclusion of motivational messages – especially related to saving or wasting money in connection with food waste (and thus exploiting the economic value of waste) or advice regarding food conservation – has been proposed as an initiative to help consumers make better and more preventive choices (WRAP, 2019). The food industry should therefore improve the sizing and clarity of labels to provide consumers with the tools to prevent food waste at home.

Furthermore, policies must consistently support these changes in production and consumption, while also promoting relationships between supply chain actors. An example of a policy that meets these aims is the Farm to Fork Strategy (European Commission, 2020), which aims at creating a carbon-neutral food system based on organic and sustainable agriculture. In addition, governments should promote

³ Information available at <https://www.bancoalimentare.it/it/news/prendere-il-progetto-foodnowaste>

⁴ More information available at <https://toogoodtogo.it/it>

investment in technologies with a high potential to build resiliency in the food sector (Boyacı-Gündüz, 2021). The adoption of sustainable practices in primary food production to enhance food system resilience is also addressed in the Farm to Fork Strategy. In fact, the strategy action plan proposes several initiatives aimed at fostering sustainable food production, such as the transformation of the Farm Accountancy Data Network Regulation (used to monitor farms' business activities and the sector-wide impact of CAP policy) into a new Farm Sustainability Data Network, to support the uptake of sustainable farming practices (European Commission, 2020); legislative initiatives to improve cooperation between primary producers in order to support their position in the food chain; and non-legislative initiatives to improve transparency (European Commission, 2020). Moreover, policy interventions targeting food waste recycling and landfill diversion could contribute to counteracting the effects of the pandemic on the food supply chain (Babbitt et al., 2021). Finally, policies should aim at consolidating positive behavioural changes that have reduced food waste since the pandemic, as summarised in Fig. 3.

4.3 Future implications

At this stage, the durability of any new, positive patterns that were developed during the pandemic should be given significant attention, to determine the long-term effects of COVID-19 on the generation of food waste. Although we are still co-habiting with the virus, we are now at a point when the first set of assumptions can be made. One conclusion we can draw is that the lockdown had a significant effect on behavioural patterns (Aday & Aday, 2020; Boyacı-Gündüz et al., 2021; Nicola et al., 2020). The unexpected closure of borders provoked a sudden shortage of labour and inputs (Aday & Aday, 2020; Boyacı-Gündüz et al., 2021; Cariappa et al., 2021), which led to trade and logistics disruptions, including reduced operational capacity (Filimonau, 2021). Such disruptions were also connected to the ripple effect provoked by changes in consumer behaviour (Aldaco et al., 2020). However, in time, the return to usual buying patterns may reduce this ripple effect. In addition, if shortages in labour diminish with the re-opening of borders and international mobility, input shortages may require greater attention. On this note, input may be increasingly affected by environmental changes due to climate change. If no action is taken to respond to this, input shortages will likely remain a challenge for many years.

Furthermore, in the early stages of the lockdown, panic shopping was registered, in connection with stockpiling (Principato et al., 2020; Rejeb et al., 2020). Considering the interrelation at that time between panic behaviours and the abrupt uncertainty caused by the pandemic (Jribi et al., 2020), it is safe to predict that such behaviours are not likely

to recur, unless a new and sudden global crisis emerges. This assumption is based on the fact that panic buying was mainly only reported in the initial stages of the pandemic (Cariappa et al., 2021; Principato et al., 2020). In addition, during the pandemic, the government and retailers had a significant influence on behaviour (e.g., by reassuring people about food shortages), and this influence is likely to be maintained. The durability of behavioural changes relating to shopping for, preparing, and managing food is more difficult to predict. In general, the use of shopping lists and meal planning, as well as better food management (Ben Hassen et al., 2021; Bogevska et al., 2021; Kubíčková et al., 2021; Pires et al., 2021; Qian et al., 2020;), including increased attention to storage and expiry dates, will probably be maintained into the future, in light of the economic impact of waste on household finances. In fact, more than a year into the pandemic, studies (Scacchi et al., 2021) reported a greater awareness of the economic impact of food waste on the part of consumers. It is hoped that, in the post-pandemic era, this greater economic awareness will be matched by an increased environmental awareness. In contrast, the extent to which consumers cook at home will likely return to pre-pandemic levels. This assumption is based on the fact that increased attention to cooking during the pandemic (and particularly periods of lockdown) was linked with more time spent at home (Amicarelli & Bux, 2020; Jribi et al., 2020). In addition, while one study (Caso et al., 2022) found an association between increased time spent engaged in consumption practices and healthier diets, when previous time constraints were reinstated after the lockdown, the consumption of healthy food products (i.e., fruit and vegetables) returned to pre-pandemic levels, while the consumption of junk food remained the same as during lockdown (Caso et al., 2022). These observations suggest that further research will be needed to assess the durability of behavioural practices that were introduced during the lockdown.

Some of the new practices that arose during the pandemic had a mixed impact on the generation of food waste, including the diffusion of food delivery. In fact, as mentioned above, the excessive flexibility offered by hospitality facilities triggered controversial behaviour in consumers. It is not easy to predict the durability of this phenomenon. However, the spread of food delivery is also implicated with environmental issues, regarding the carbon footprint, food waste, and plastic waste due to packaging (Chen et al., 2021; Filimonau, 2020; Li et al., 2020; Liu et al., 2021). Indeed, the increased use of food packaging during the pandemic, connected with increased food delivery, sheds light on the need for packaging that is biodegradable and able to conserve nutritional value, with a low environmental impact (Kochanska et al., 2021). To this end, it has been suggested that the application of technology to convert food waste into sustainable materials (e.g., bioplastics) may support the transition toward a circular

economy in the food sector and relieve agriculture of the current burden of producing bioplastics (Kochanska et al., 2021). Moreover, ethical issues correlated with food delivery merit close attention, especially in connection to the economic and human treatment of delivery workers. Although these workers put their health at risk during periods of contagion, they are often subject to poor working conditions, resulting in job dissatisfaction (Li et al., 2020). As a result, there has been a global call to improve the treatment of these workers, suggesting that policymakers should intervene to regulate their rights and improve their working conditions (Li et al., 2020).

4.4 Limitations of the present study

The discussion presented above is subject to several limitations, which will now be addressed. First, the study was primarily focused on consumer food waste, in connection with only one stage of the food supply chain. Therefore, it could be argued that, by partially neglecting the other stages of the supply chain, it provided a limited picture of the effects of the pandemic on the generation of food waste. In fact, as emerged in the discussion, all stages in the supply chain exert a mutual influence on each other (Aldaco et al., 2020). Hence, in light of the interconnections throughout the chain, future research should focus on earlier stages of the food supply chain, to provide a broader picture of changes in the food system due to the pandemic. However, it should also be noted that this limitation stemmed directly from the bias in the literature in favour of consumer behaviour studies – a fact that limited the extent to which we could enquire into other stages of the value chain.

In addition, there was a relevant methodological limitation to the study. As mentioned above, the review targeted and included only white literature, which, despite its high relevance, could provide only partial insights, compared to a wider set of publications that also included grey literature. For this reason, references to grey publications were used to complement the discussion, stressing the relevance of the points made. Future research should expand the selection of publications to broaden the scope of the study.

Lastly, the majority of the investigated papers reflected mainly on consumers' changed perceptions of food waste, rather than their real changes in the volume of food waste generated. As mentioned above, most of the studies collected data via surveys and questionnaires, which could only shed light on consumers' reasons for engaging in behaviour that resulted (or not) in food waste (UNEP, 2021); such measures could not, however, measure precise quantities of food waste. The limitations of self-report also applied, and further complicated the scenario. On the one hand, the so-called value-action gap (Sharp et al., 2021), which describes the mismatch between intention and actual behaviour, leads us to reflect on whether consumers' reported changes in behaviour

accorded with actual changes in practice. On the other hand, we cannot exclude the possibility that some positive reported changes resulted from the so-called social desirability bias, which holds that behaviours that are perceived to be acceptable and regarded favourably by others are more likely to be reported (Sharp et al., 2021).

Future research should therefore focus on the durability of the habits and practices that consumers developed as a result of the pandemic, as well as the impact of some of these practices (e.g., food delivery) on the environment. More significantly, research should explore whether the opportunity provided by the pandemic to build a more resilient food system has been met with long-lasting changes in practices, policies, and modes of production. As the impacts of climate change are expected to increase each year, the issue of resilience in the food system will require greater focus over time.

5 Conclusions

The global challenge of food waste has been attracting increased attention by scholars, in light of its significant environmental and economic implications (UNEP, 2021). As the effects of climate change become more and more evident, food systems must increase their resiliency to survive (Boyacı-Gündüz et al., 2021). A resilient food system relies on sustainable practices that reduce the overall impact on the environment. From the literature review conducted in this study, it can be argued that the pandemic changed consumers' perceptions of food-related behaviours, resulting in a perceived reduction in food waste in some cases (Babbitt et al., 2021; Ben Hassen et al., 2021; Pappalardo et al., 2020; Principato et al., 2020). In addition, consumers reported that they acquired greater awareness of the environmental and economic impacts of food waste (Pappalardo et al., 2020; Pires et al., 2021; Qian et al., 2020) during the pandemic. These reported changes may have varied according to a cluster of factors, ranging from socio-demographic characteristics such as gender and age (Amicarelli et al., 2021; Jribi et al., 2020; Muresan et al., 2022; Qian et al., 2020; Vidal-Mones et al., 2021;), to socio-economic factors such as price and income employment insecurity (Babbitt et al., 2021; Cequea et al., 2021; Jribi et al., 2020; Qian et al., 2020; Roe et al., 2020; Schmitt et al., 2021; Vargas-Lopez et al., 2021). Therefore, it could be argued that the pandemic increased consumers' intentions to develop sustainable patterns and lifestyles. Although these practices seem to have been motivated by primarily economic (rather than environmental) concerns over food waste (Cequea et al., 2021; Jribi et al., 2020), the adoption of more sustainable behaviour supports progress toward desired goals, including the SDGs. Furthermore, the COVID-19 crisis exposed vulnerabilities and contradictions in the food system (Boyacı-Gündüz et al.,

2021), provoking disruptions in production, processing, and distribution, as well as shocks to supply and demand (Aldaco et al., 2020; Boyacı-Gündüz et al., 2021; Di Marcantonio et al., 2021), with a consequent impact on food waste. It particularly strained systems that were already suffering from structural difficulties (Blazy et al., 2021). However, it also triggered beneficial changes in production and consumption, such as the application of technological tools to prevent and mitigate food waste (Strotmann et al., 2021). Nonetheless, policy makers should work to develop policies and strategies aimed at maintaining these newly reported practices during the pandemic, triggering circular patterns of production and consumption, achieving shorter food supply chains, and encouraging greater integration among actors along the entire food value chain (Aldaco et al., 2020; Galanakis, 2020). It is hoped that consumers' increased awareness and better food practices will be supported by policies to ultimately reduce food waste.

Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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